SLIO-CAN BASED ACTUATION SYSTEM FOR GREENHOUSE CONTROL

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Abstract - This paper describes a system developed to implement the actuation after the data acquisition and processing from the plant. It was implemented over a previous developed CAN network [1], based on the 80C592[2] microcontroller from Philips implementing a hierarchical structure to form a tree topology. In this network a Personal Computer is connected through a Net Manager to units named Masters, located at the greenhouses, that allows the management of several secondary units named Slaves. This units are implemented using a SLIO (Serial Linked I/O device) [3] from Philips, making possible the greenhouses control. This choice is due to the fact that the SLIO allows a cheaper solution to applications where no high speed requirements are needed such as the on/off functions. The assembling of the actuators within a greenhouse allows the use of an architecture whose communication is done through the main power cables. As mean of communication is used the CAN (Controller Area Network) [4] protocol, which has a great flexibility and robustness needed in real-time control. The system, must allow easy expansion and configuration without compromising its performance. This is the case when the parameters must be changed whenever the weather conditions (Summer/Winter), force us to modify the setpoints of several control variables such as: temperature, light, humidity, among others.

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I. INTRODUCTION

The increasing importance of greenhouse production is due to the necessity of achieving with success, cultures in environments and/or seasons that from the first point of view wouldn't be the most favourable, as well to produce high quality plants. This objective requires the design and implementation of systems to control the relevant variables such as temperature and humidity for the air and soil, radiation, etc.

The action that a control system can exercise over the environmental factors on a agricultural greenhouse, is limited by the actuation equipment's available: heating systems, CO_2 injectors, ventilators, shading curtains, etc. The following session describes the most common actions and equipment's used for the control of the mentioned variables.

A. *Heating*

In many cases, the protection given by the greenhouse is sufficient to allow the culture to develop during winter without the use of heating systems.

A greenhouse with heating facilities when compared with one, which does not have it, presents the following advantages:

- Production speed increased
- Possibility of producing products out of its season
- Better control of diseases, since the heating helps to prevent the occurrence of high levels of humidity.
- Depending on the fuel and the burning system used, it can be possible to make CO_2 enrichment.

The greenhouses can be heated by several ways. The heating can be done upon the interior atmosphere, the soil or both. Generally, the heating of the air is done with circulation of hot water in tubs, indirect heat, or using air forced heaters, direct heating. In the soil is generally used a net of tubes, buried or at the surface (in this case the air is also heated) where water circulates with a temperature that generally varies from 20 to 25 ^{0}C.

The direct heating systems have the advantage of a quicker time response.

Most of the heating systems installed in greenhouses are of the following types:

1. Hot water Systems
2. Steam Heating Systems
3. Unit Heater and Radiant Heaters

The basic concepts of the several alternatives of heating systems and how to calculate the heating requirements are described at [5].

B. *Cooling*

There are several processes to lower the temperature in a greenhouse. Those are:

1. Using shadow nets
2. Water circulation(without and with filters) through the greenhouse cover
3. Through forced or natural ventilation
4. Humidify the air through water evaporation, or by the injection of tiny drops of water in the air.

In the first case the shadow nets are used to create an artificial shadow, this will decrease the solar radiation energy that enters the greenhouse. The shadow nets can be static or dynamic, but the dynamics are the ones with interest for the automation systems. The movable systems, that uses motors and position detectors are normally installed inside the greenhouse. The placement of this systems outside the greenhouse presents some inconveniences such as the risk of being damaged through several weather conditions, like by winds.

In the second case, a water film with a colour substance circulates on the greenhouse cover, with the use of a pump and pierced tubs. This allows increasing the reflecting capability and the water will absorb part of the solar rays.

This method presents several disadvantages such as: it can't be used in a large number of areas due to the lack of water, and also because the water used in this method must be soft so that the diffusers won't be obstructed and to prevent the deposit formation on the covering.

Natural ventilation, is performed by opening the windows and/or another mobile surfaces on the greenhouse. On an automated system the motor control for opening and closing the windows, must be established by steps to avoid an abrupt temperature variation. The speed and direction of the wind, the outside temperature and the precipitation must also be taking in consideration to establish this control action.

Whenever the natural ventilation is insufficient, it is necessary to use forced ventilation. This is done using one or more ventilators. Usually they should assure a complete renovation of the greenhouse air in a short time period (typically 2 minutes for the summer season) in order to keep the temperature stable within acceptable levels [6].

The ventilators are equipped with shutters that open by a centrifugal effect as soon as it starts working. This allows reducing the heater losses, on the periods when the outside temperature is low. Normally the ventilation systems will not allow the decrease of temperature in a substantial way.

The cooling efficiency can be increased by the combined action of the natural and forced ventilation systems with air humidifiers. It will be described some of the most used air humidifier systems. The fog systems are formed by suspended tubes on the greenhouse structure that inject into the greenhouse atmosphere, tiny drops of water that contribute to increase air humidity and to decrease the air temperature. To achieve this effect, the water in the tubs must be under high pressure, for that it is necessary a device that measure the hydrostatic pressure (typically 100 bar) and it is also necessary to install micro diffusers on the tubes.

This process presents a disadvantage, it can originate diseases because it produces a high level of humidity and it maintains the plants wet during long periods.

Other type of cooling system uses a porous pad installed in one side of the greenhouse, which is maintained wet (by opening a valve that allows water to follow over it). On the opposite side of the greenhouse is installed an exhaust fan. With this, the injected air from the outside wich circulates through the pad, will make possible to decrease significantly, by evaporation effect, the inside temperature. A more detailed description of this system is available in [7].

C. Carbon Dioxide

The plants assimilate the carbon from the dioxide carbon present in the air to realise photosynthesis. Its normal concentration in the air is approximately 330 ppm. If there is an increase the CO_2 concentration at the greenhouse, and simultaneously favourable conditions of temperature and light are verified, it will possible achieve a bigger development of the plants. To achieve this objective it is necessary to inject CO_2. The CO_2 injection may be done through two ways. On the first one are used the resulting gases from the propane and natural gas combustion of burning devices, on the second process is used the resort to pure carbon dioxide stored in bottles.

To distribute it through the greenhouse it can be used the heating and/or ventilation conducts or dedicated polyethylene pierced tubes across the greenhouse. The gas suply is regulated by the action of valves that force the carbon dioxide and the air to circulate through tubes in order to achieve a uniform distribution on the greenhouse. The carbon dioxide concentration must be determined with respect to the plants and to the other environmental conditions [8].

II. GLOBAL CONTROL SYSTEM

A control system consists of a combination of hardware and software that acts as a supervisor with the purpose of managing the controlled system. This is done by the use of a control loop. A control loop consists of three main components: 1) The acquisition of data through sensors, that is responsible for monitoring the state variables, 2) the processing component where is compared the sate variables with their desired state, deciding what must be done to change the state of the system, and 3) the actuation component carrying the necessary actions. Performing these actions requires a combination of hardware and software that must be implemented for each specific application.

The actuation component is the one, that serve as base for this paper and the one that will be describe with more detail. The control system[1] is showed in the block diagram of Fig.1. For communication is used the CAN protocol, because it is a simple, low cost and robust network designed to work in noisy and harsh environments and is optimised to real time control. CAN was originally developed by Bosh for the automotive industry. It is a ISO[4] standard since 1993. As a consequence of its high performance and low cost, CAN as been implemented in several areas, not only in the automotive industry but also in many other industrial applications and medical areas.

Due to the requirements in the greenhouse, control applications, the CAN network seems to be a good option because it allows the implementation of economical and reliable systems.

With CAN, bit rates up to 1M bit/s are allowed[4], and the communication is done in a robust and flexible way since the protocol is fault tolerante and allows the expansion of the system without compromise its performance.

The data acquisition part of this system[1] is composed by several secondary units named Slaves connected to a Master station responsible by them, on a bus topology. Realised tests presents results without errors to distances that fall from 40 to 1100 meters. This work deals with the actuation component that is done by SLIO CAN based cards.

On the processing part, developed works implement useful control algorithms using Fuzzy Logic[9], PID, Adaptive Climate Control [10] and others. As result of these algorithms, orders will be sent to the actuation part that will be described bellow.

III. ACTUATION NETWORK

A. Network Topology

As reported on the abstract, this component of the greenhouse climatic control system is based on the 80C592 microcontroller with CAN and on the SLIO P82C150 from Philips. The first one the main unit of the intelligent block, named Master, which is responsible for the state monitoring of all the Slave units, distributed through the greenhouse and which has as base element the SLIO[3].

The state monitoring is done by message exchange between the master and all the remaining units. The slave units allow, through power drive circuits, the generation of the actuation signals according to the devices used for the control of the different physical parameters as described on the introduction.

The MASTER/SLAVE configuration is illustrated on the block diagram of Fig.2.

The block designated as Master is basically composed by a transceiver[12] that does the connection to the CAN bus, the 80C592 microcontroller and some peripherical devices such as auxiliary memory, embedded CAN controller, CAN interface with Stand Alone CAN Controller 80C200, real time clock based on the DS1287, analog and digital channels, interface TTL/RS232, among others. This block is responsible for CAN communication, slave monitoring, sending messages to the slave units whenever is necessary, and for communication with the central system unit[1] through CAN. This Master unit illustrated in Fig.3 serves as router situated on the greenhouse, possessing enough intelligence to have information processing.

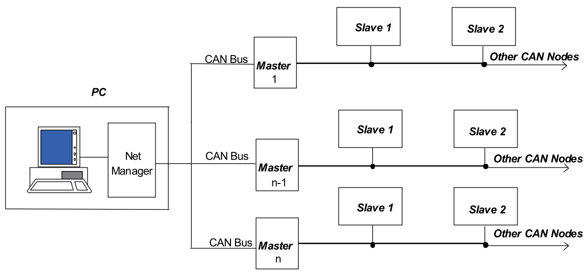

Fig.1. Global Control System

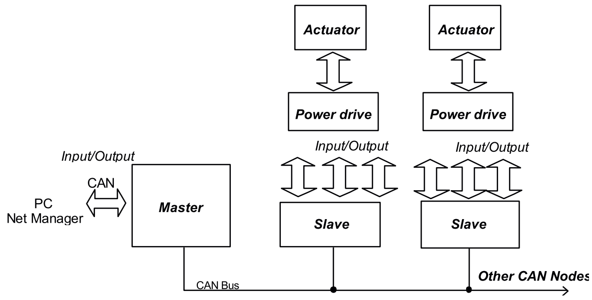

Fig.2. Master/Slave configuration

In applications, like this, that involves in the majority of cases, on/off functions, the use af a can controller configuration will be not advantageous. This is due to the fact that there is a waste of the transmission bandwidth and resources using the high speed CAN controller configuration for low speed (<125 Kbit/s) control. Since, SLIO CAN was developed to present advantages of CAN technology in low speed applications at lower cost this integrated circuit was applied to the slave unit. Beyond that, it is ideal to activate remote sensors, actuators and collect analog or digital data. It's also an integrated circuit that can act as a dumb I/O gateway on a CAN network, able to transform messages into real digital I/O signals. It can also read I/O pins and transmit them as messages to other CAN nodes in the network. SLIO is a low intelligent chip for simple I/O functions, that needs to be programmed and controlled by an intelligent unit that in this case placed on the Master unit. Therefore, SLIO units can be viewed as remote units of a central microcontroller.

Beyond this general characteristics SLIO[3] possesses 16 configurable digital or analog I/O port pins, fully integrated clock oscillator, each of the port pins individually configurable via CAN-bus (port direction, port mode and event capture facilities for inputs (event driven or polling)), automatic bit rate detection and calibration, among others. It is also important to refer that due to its four bit identifier a maximum of 16 different identifiers is allowed. Therefore it is possible to have 16 SLIO units controlled by one Master. The communication with the Master is done meeting the CAN protocol specification, version 2.0 A and B (passive)[13].

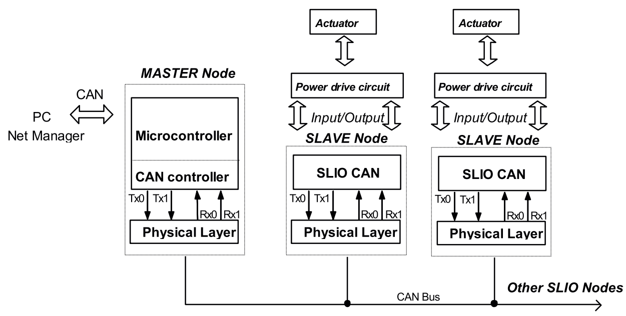

Fig.3. Master/Slave configuration using SLIO

Fig.3 shows the Slave unit with SLIO that performs the interpretation of the CAN messages sent by the Master. According to that, the output signals are generated and applied to the power drive circuits. The sensitivity to the analog or digital inputs is of different types[3]: polling or event capture if the input is configured as digital or by reading a Analog-to-Digital Conversion (ADC) Register if the input is configured as analogue.

Depending on the actuator, the unit that was named as power drive circuit can be based on relays if on/off control is needed, as it is, in the majority of the cases. The system that is being implemented has several actuators that require this type of control like: shadow nets, valve's control to CO_2 injection and/or indirect heating by hot water circulation, natural ventilation by opening and closing windows, etc.

If it is necessary a different sort of control like for instance control the air flow of a exhaust fan ventilator, the corresponding CAN node and the power drive circuit must of a different kind. The change is because beyond the activation and inhibition of the ventilator, this node must allow another features. To achieve that its necessary to modify the structure of this slave, using not a SLIO but another more intelligent unit able to process information and with more capabilities like PWM outputs, Analog to Digital Converter among others.

A PWM inverter transforms PWM signals into power signals. In this application, it will be used such device, and through it, will be possible the motor speed adjustment by PWM signals sent from a microcontroller [14]. A generically block diagram is illustrated on Fig. 4.

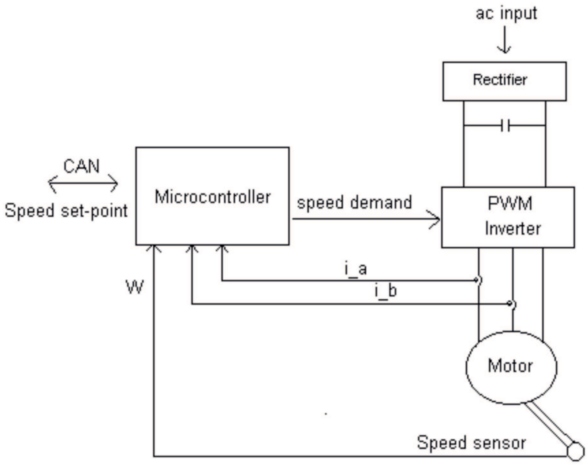

Fig.4. Adjustable-Speed Control of an AC Motor

To achieve this objective it's used the 80C592-microcontroller and by this way, it's possible to get different airflow. This unit placed near to the actuator receives CAN messages containing the required speed set point from the Master. In addition, this slave must be able to read the speed sensor output and remote measurement of two-phase current (i_a and i_b), and generate PWM signals that adjust the motor speed to the received set-point.

Only the microcontroller located at the Master unit will be responsible for calibration and Slave's monitoring. All others CAN intelligent nodes will also be able to receive the broadcast SLIO transmitted messages, but do not act upon the data, because that will lead the system to errors. The block diagram of this improved Master/Slave configuration is illustrated in fig.5.

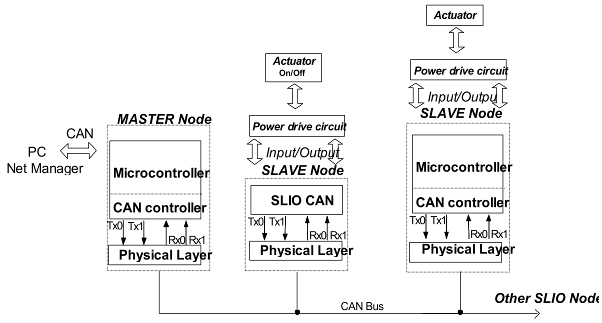

Fig.5. Master/Slave configuration to several control possibilities

B. Network Software

The software to the actuation network deals with messages interchange between the Master unit and all the slaves following the CAN specification 2.0[13]. This message interchange is done using four different types of frames: Data Frame, showed on Fig.6 Remote Frame; Error Frame and Overload Frame. The Remote Frame is not used on SLIO[3] transmissions.

To be processed by the SLIO node Data and Remote frames must be in standard Format with 11 identifier bits. Frames with extended identifier (CAN version 2.0 B) are ignored.

Start	Arbitration	Control	Data	···	Data	Crc	Ack	End

Fig.6. Data Frame

Data Frames transmitted by the SLIO contain tree data bytes [3]. The first byte is composed by four bits of status information, the register address and two more bytes with the contents of the addressed I/O register. This enables the Master node to verify that the addressed register has correctly been written in case of writeable registers, and to read the contents in case of readable registers. After each successful message transmission, SLIO delays the transmission of a possible further pending message for three bit times and with that other CAN nodes with lower identifier priority have the opportunity to transmit a message.

Received and transmitted Data Frames have the same format only a DIR-bit (ID.0) in the arbitration field is different.

Remote Frame is another important type of Frame because SLIO will answer to this Frame with a Data Frame containing the corresponding Data Input Register.

The priority level is assigned by attribution of identifiers, in a manner that the device with the higher identifier messages has the lower priority messages. Using the configuration with a Master, and both SLIO and microcontroller based slaves, the priority is assigned in a manner that the higher priority is assigned to the Master, then to the microcontroller and SLIO based slave units respectively. One solution to the priority assignment is shown on Fig.7, where are attributed the lower identifiers to priority messages like alarm signals. Some identifiers are not attributed on propose because it could be necessary to expand the network with units that require more priority than some already existing ones. So when for instance the Master unit and the microcontroller based slave intend to transmit simultaneously the one with high identifier messages will lose and the other (Master) will win the access to transmission.

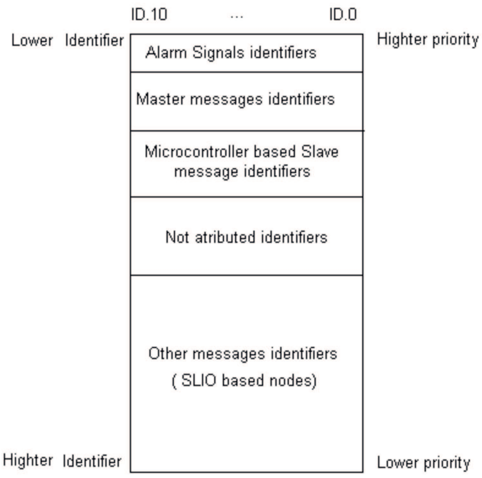

Fig.7. Messages priority attribution

In the CAN Network [4] the medium access is a Carrier Sense Multiple Access with Collision Detect (CSMA/CD) where: if serial bus is busy nodes delay the transmissions; when a bus idle conditions is detected, any node may start transmitting; bus access conflicts are solved through the bitwise comparison of the messages identifiers as follows:

- While transmitting a message identifier , each node monitors the serial bus-line;
- If the transmitted bit recessive and a dominant bit is monitored, the node gives up from transmitting and starts to receive incoming data;
- The node transmitting the message with the lowest identifier goes through and gets the bus.

So by this contention-based arbitration using the identifier, neither information or time is lost.

When a node gets the bus it transmits the message in fixed format frames of different but limited length, to all other nodes on the network, then all the receiver nodes may accept or not the information based upon a process called "Frame Acceptance Filtering", which decides if the receiving information is relevant or not to that node. If the information is relevant then the node will actuate in consonance with the incoming messages else the node will ignore that.

IV. CONCLUSIONS

It was described an actuation system to integrate a greenhouse control architecture. The system is based on the SLIO, which uses the CAN with their main advantages: robustness and design flexibility. This solution is very attractive and worth due to its high performance and low cost ratio. It can be calibrated, programmed, controlled and checked by a host controller, and has great analog and digital I/O capabilities.

This is part of a global project concerning with the development of an electronic system for greenhouses. Experimental greenhouses were built to test the data acquisition systems and the control strategies developed so far.

Using the facilities, tests will be realised to analyse the functionality and robustness on the communication and of the proposed actuation system.

V. ACKNOWLEDGMENT

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